# 1.7 Determining Stopping Distance

Figure B1.41: Stopping distances vary from driver to driver.

## Reaction Distance

Reaction time plays a critical role when a driver has to stop a vehicle. The time required to react includes the time it takes the driver's brain to recognize that there is a need to stop and the time it takes the driver's foot to move from the gas pedal to the brake pedal. Since the reaction time varies from driver to driver, so does the **reaction distance**.

reaction distance: the distance a vehicle travels while the driver is reacting

## Practice

36. Recall the "Reaction Time" activity at the beginning of this chapter. In that activity your partner dropped a metre-stick from rest, and then you grabbed it between your forefinger and your thumb. The metre-stick had an initial velocity of zero and was accelerated by gravity until you caught it.
    a. If the metre-stick was able to fall 22.5 cm before you caught it, calculate the length of time it fell.
    b. Based on your calculations to question 36.a., state the reaction time for this trial.
    c. List some factors that could cause a driver's reaction time to be longer.

## Braking Distance

Once the driver starts to press the brake pedal, the vehicle begins to slow down; but, as you know, stopping takes time. Road conditions, the condition of the vehicle's tires, and the condition of the vehicle's brakes are factors that influence the time needed to stop the vehicle. These factors all influence the car's deceleration.

Since deceleration varies for different vehicles under different weather conditions, the **braking distance** varies as well.

braking distance: the distance a vehicle travels from the moment the brakes are first applied to the time the vehicle stops

## Practice

37. Each winter on the day of the first significant snowfall—where snow is accumulating on the roadways—appears, it is not unusual for there to be more collisions than on any other day during the year. Explain the connection between the large number of collisions that occur on this day and the change in road conditions.

## Stopping Distance = Reaction Distance + Braking Distance

Example Problem 1.19 will show that calculating the stopping distance for a vehicle requires careful thought about the two components of stopping: the motion of the vehicle while the driver is reacting and the motion of the vehicle while the driver is braking. An organized solution helps to keep all these details straight.

## Example Problem 1.19

The typical reaction time for most drivers is considered to be about 1.50 s. This includes the time required to identify the danger (0.75 s) and the time required to react to the danger (0.75 s). The ability of vehicles to decelerate varies greatly however. Traffic safety engineers often use a deceleration value of 5.85 m/s$^2$ to calculate the minimum stopping distance for a vehicle on smooth, dry pavement.

Determine the distance travelled while reacting, the distance travelled while braking, and the minimum stopping distance of a vehicle travelling 110 km/h.

### Solution

Vector notation is dropped since solving for braking time involves dividing initial velocity by acceleration and since the question asks for distance.

Note that during the time interval when the driver reacts, the vehicle's motion can be considered to be uniform motion.

Calculate the distance travelled while reacting.

$$\Delta t = 1.50\ s$$

$$v = 110\ \frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ s}$$

$$= 30.\overline{5}\ \text{m/s}$$

$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$

$$\Delta d = v\Delta t$$

$$= (30.\overline{5}\ \text{m/s})(1.50\ s)$$

$$= 45.8\overline{3}\ \text{m}$$

$$= 45.8\ \text{m}$$

The distance travelled while reacting is 45.8 m.

continued on next page

Next, calculate the braking distance.

$v_i = 30.\overline{5}$ m/s

$v_f = 0$

$a = -5.85$ m/s$^2$

$\Delta t = ?$

$\Delta d = ?$

First, determine the time it takes to stop the vehicle.

$$a = \frac{v_f - v_i}{\Delta t}$$

$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$

$$\Delta t = \frac{-v_i}{a}$$

$$= \frac{-(30.\overline{5} \text{ m/s})}{-5.85 \text{ m/s}^2}$$

$$= 5.223\,171\,89 \text{ s}$$

Next, determine the braking distance.

$$\Delta d = \left(\frac{v_i + v_f}{2}\right)\Delta t$$

$$= \left(\frac{30.\overline{5} \text{ m/s}}{2}\right)(5.223\,171\,89 \text{ s}) \quad \leftarrow v_f = 0$$

$$= 79.798\,459\,43 \text{ m}$$

$$= 79.8 \text{ m}$$

The braking distance is 79.8 m.

Determine the stopping distance.

$$\Delta d_{stopping} = \Delta d_{reaction} + \Delta d_{braking}$$

$$= 45.8\overline{3} \text{ m} + 79.798\,459\,43 \text{ m}$$

$$= 126 \text{ m}$$

The stopping distance is 126 m.

## Practice

38. Use the typical driver reaction time of 1.50 s and the representative deceleration of –5.85 m/s$^2$ to calculate the distance travelled while reacting, the distance travelled while braking, and the minimum stopping distance on smooth, dry pavement for a vehicle with an initial velocity of
    a. 100 km/h
    b. 80.0 km/h

## DID YOU KNOW?

In the *Basic Licence Driver's Handbook*, you'll find a chart that gives the stopping distances for a number of highway speeds. You can find this handbook on the Internet by using a search engine and entering the key words *Alberta Transportation and Basic Licence Driver's Handbook*. The same techniques used in Practice question 38 were used to generate this chart. You can compare the stopping distance you calculated with those in the chart in the *Basic Licence Driver's Handbook*.

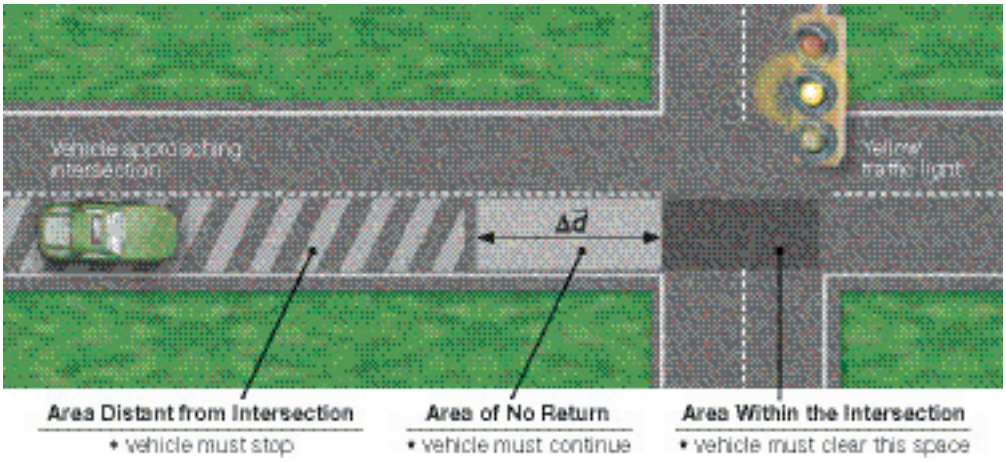
## Controlling Traffic at Intersections

Earlier in this chapter you saw how the concepts of acceleration, velocity, and displacement are used in the design of acceleration and deceleration lanes. Traffic safety engineers also use these ideas when they calculate the optimum length of time that the light at an intersection should stay yellow.

Figure B1.42: The length of time a traffic light remains yellow varies from intersection to intersection.

To understand how the timing of traffic lights at an intersection is determined, it is essential to first understand the purpose of the yellow traffic light. The yellow light is a signal to motorists that the light is about to turn red. For drivers approaching an intersection, the yellow light means they should prepare to stop. For drivers who are already in the intersection—waiting to complete a left turn—the yellow light means they should clear the intersection by passing through it. These two meanings of the yellow light cause problems when vehicles are in a third place called "the area of no return" (as shown in Figure B1.43). A vehicle in the area of no return is too close to the intersection to stop safely and, therefore, must proceed through the intersection.

Figure B1.43: The area of no return is highlighted.




The area of no return is a space that drivers must learn to recognize and attempt to avoid. If drivers fail to stop before entering this region, they risk the possibility of passing through the intersection when the light is red. Running a red light is exceptionally dangerous, and it can result in a hefty fine and demerit points against your licence.

Although drivers learn, through experience, to estimate the boundaries of the area of no return, the length of this space can be calculated. In fact, as you'll see in Example Problem 1.20, the length of the area of no return (represented by $\Delta\vec{d}$ in Figure B1.43) can also be used to estimate the length of time the light should remain yellow.

## Example Problem 1.20

A vehicle travelling at the posted speed limit of 60.0 km/h approaches an intersection where the light has just turned yellow.

**a.** Using the typical reaction time of 1.50 s and the representative deceleration value of 5.85 m/s$^2$, calculate the minimum stopping distance for this vehicle.

**b.** Explain why it is reasonable to assume that the minimum stopping distance is also the length of the area of no return for this traffic light.

**c.** Use your answer from part a. and the initial speed of the vehicle to estimate the time required for a driver to travel through the area of no return with uniform motion.

**d.** Drivers who have entered the area of no return should be able to travel with uniform motion to the intersection while the traffic light remains yellow. Use your answer from part c. to determine the minimum length of the time the light should remain yellow at this intersection.

Solution

**a.** Vector notation is dropped, since solving for braking time involves dividing initial velocity by acceleration and since the question asks for distance.

Determine the reaction distance.

$$v = 60.0\,\frac{\text{km}}{\text{h}} \times \frac{1000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3600\ \text{s}}$$
$$= 16.\overline{6}\ \text{m/s}$$

$$\Delta t = 1.50\ \text{s}$$
$$\Delta d = ?$$

$$v = \frac{\Delta d}{\Delta t}$$
$$\Delta d = v\Delta t$$
$$= (16.\overline{6}\ \text{m/s})(1.50\ \text{s})$$
$$= 25.0\ \text{m}$$

continued on next page

The reaction distance is 25.0 m.

Determine the braking distance.

$v_i = 16.\overline{6}\ \text{m/s}$ $\quad \Delta t = ?$

$v_f = 0$ $\quad \Delta d = ?$

$a = -5.85\ \text{m/s}^2$

First, determine the time it takes to stop the vehicle.

$$a = \frac{v_f - v_i}{\Delta t}$$

$$a = \frac{-v_i}{\Delta t} \quad \leftarrow v_f = 0$$

$$\Delta t = \frac{-v_i}{a}$$

$$= \frac{-(16.\overline{6}\ \text{m/s})}{-5.85\ \text{m/s}^2}$$

$$= 2.849\,002\,849\ \text{s}$$

Next, determine the braking distance.

$$d = \left(\frac{v_i + v_f}{2}\right)\Delta t$$

$$= \left(\frac{16.\overline{6}\ \text{m/s} + 0}{2}\right)(2.849\,002\,849\ \text{s})$$

$$= 23.741\,690\,41\ \text{m}$$

$$= 23.7\ \text{m}$$

The braking distance is 23.7 m.

Determine the stopping distance.

$$\Delta d_{\text{stopping}} = \Delta d_{\text{reading}} + \Delta d_{\text{braking}}$$

$$= 25.0\ \text{m} + 23.741\,690\,41\ \text{m}$$

$$= 48.741\,690\,41\ \text{m}$$

$$= 48.7\ \text{m}$$

The minimum stopping distance is 48.7 m.

**b.** The minimum stopping distance is the shortest distance in which a driver travelling 60.0 km/h can stop the vehicle. So, at this distance, or any distance longer than this, a vehicle will be able to stop. For any distance less than the minimum stopping distance, the driver must continue through the intersection because the vehicle cannot be stopped before entering the intersection.

continued

**c.** $v = 16.\overline{6}\ \text{m/s}$

$\Delta d = 48.741\,690\,41\ \text{m}$

$\Delta t = ?$

$$v = \frac{\Delta d}{\Delta t}$$

$$\Delta t = \frac{\Delta d}{v}$$

$$= \frac{48.741\,690\,41\ \text{m}}{16.\overline{6}\ \text{m/s}}$$

$$= 2.92\ \text{s}$$

The time required to travel through the area of no return with uniform motion is 2.92 s.

**d.** If a driver travelling 60.0 km/h needs 2.92 s to travel through the area of no return, then the traffic light should remain yellow for at least this length of time. Therefore, the traffic light should remain yellow for at least 2.92 s.

## Estimating the Minimum Length of Time for Yellow Lights

The method shown in Example Problem 1.20 is a simplified version of the technique used by traffic safety engineers when they determine the length of time for yellow lights. Even though the professionals use a more advanced technique that includes other variables, such as the length of the intersection, the method shown here allows you to determine a reasonable estimate for the minimum length of time for a light to remain yellow.

### Practice

39. Use the typical reaction time of 1.50 s and the representative deceleration of 5.85 m/s$^2$ to calculate the minimum time interval for yellow lights at intersections with the following posted limits.
    a. 70 km/h
    b. 90 km/h
40. As the posted speed limits increase, describe the trend in the values of the minimum time intervals for the yellow light.
41. Provide an explanation for the relationship between the posted speed limit and the length of time (duration) of the yellow light at an intersection.
42. A common cause of collisions at intersections is the tendency of some drivers to accelerate when they see that the light has turned yellow. Explain why this is a dangerous practice.

## Investigation

### Traffic Lights—Designing a Field Study

**Science Skills**

- ✓ Initiating and Planning
- ✓ Communication and Teamwork

#### Purpose

You will design a field study that will verify that the simplified method actually does provide reasonable estimates of the minimum time interval for a yellow light at a given intersection. If intersections have significant differences between the measured time interval of the yellow light and the calculated time interval, additional observations would be needed to account for the discrepancies.

#### Background

Earlier in this chapter it was stated that the method shown for determining the minimum time interval for a yellow traffic light was a simplified approach. This investigation involves designing a field study. These minimum time intervals, which can be calculated using the techniques shown in this chapter, will be compared to the actual time intervals of the yellow light measured at a given intersection.

#### Process

The end product will be a detailed procedure for a field study. In this procedure you'll describe how to complete the necessary measurements and observations to compare the predictions made using the model. Your procedure should address the following:

step 1: Identify specific questions that need to be investigated to answer the questions posed in the purpose of the investigation. You should generate at least four new questions.

step 2: Determine the data that needs to be collected to answer each of the questions posed. Describe a means to collect that data, and list the tools that will be required.

step 3: Design and construct data tables to ensure that all the necessary observations are made and recorded.

step 4: Describe the safety precautions that should be used if you were to go to intersections to collect the data. You should include at least four specific strategies to keep yourself and other students safe during this field study.

Figure B1.44: The simplified method provides a reasonable estimate of the minimum time a traffic light remains yellow at any given intersection.

## 1.7 Summary

All the equations in this chapter for describing uniform and accelerated motion were used to determine the stopping distance for a vehicle travelling at a given speed. Stopping distance is the sum of the reaction distance (the distance a vehicle travels while the driver is reacting) and the braking distance (the distance a vehicle travels from the moment the brakes are first applied until the instant the vehicle stops).

Knowledge from previous lessons was used to estimate the minimum length of time for a traffic light to remain yellow at an intersection. This time is approximately equal to the length of time for a vehicle to travel through the area of no return with uniform motion. The area of no return is an important space for a driver to recognize when approaching an intersection because accidents are more likely when drivers find themselves in this space.

Figure B1.45: Stopping distances not only vary from driver to driver, they also vary according to road conditions.

## 1.7 Questions

### Knowledge

**1.** The typical reaction time for most drivers is _____.

**2.** The reaction time is the sum of the time it takes for a driver's brain to recognize that there is a need to stop and the time it takes for the driver's foot to reach the brake pedal. Identify the term that describes the motion of a vehicle during the reaction time.

**3.** The braking time is the time it takes for a vehicle to come to a complete stop from the instant the driver's foot hits the brake pedal. Identify the terms that describe the motion of a vehicle during the braking time.

### Applying Concepts

**4.** A vehicle is travelling 105 km/h on a highway when the driver sees a moose in the middle of the lane.

**a.** Determine the distance travelled by the vehicle while the driver is reacting. Assume the driver's reaction time is 1.50 s.

**b.** Determine the braking distance, assuming a deceleration of 5.85 $m/s^2$.

**c.** Determine the stopping distance.

**d.** Determine a new stopping distance for this vehicle if the driver was impaired and had a reaction time of 3.00 s.

**e.** Explain why it is so dangerous to drive a vehicle while under the influence of drugs or alcohol. Does the same generalization apply to other impairments to reaction time, such as distractions? Identify some distractions commonly found in motor vehicles.

**f.** Determine a new stopping distance for the vehicle if the surface of the road is wet and the deceleration of the vehicle is reduced to 2.50 $m/s^2$. Assume that the reaction time of 1.50 s still applies.

**g.** Explain why posted speed limits represent the maximum speed under ideal conditions and not the speed you should travel.